Technologies for the James Webb Space Telescope

The James Webb Telescope (JWST) will have a unique and profound role in transforming our understanding of astrophysics and the origins of galaxies, stars, and planetary systems. To do this, and build on the successes of Hubble and Spitzer, it has invested in innovative and powerful new technologies ranging from optics to detectors to thermal control systems. JWST has made an early and significant investment in its technologies, and as a result, all are on schedule to be fully demonstrated during 2006.

JWST Technology Demonstration Schedule	
Near Infrared Detectors	Complete
Sunshield Materials	Complete
Lightweight Cryogenic Mirrors	June 2006
Mid-Infrared Detectors	July 2006
Micro-shutter Arrays	August 2006
Cryogenic Detector Readout ASICs	August 2006
Cryogenic Heat Switches	September 2006
Large Precision Cryogenic Structure	November 2006
Wavefront Sensing & Control	December 2006
Cryocooler	December 2006

Lightweight Cryogenic Mirrors

When it comes to telescopes, size matters: the sensitivity of a telescope is directly proportional to its collecting area, and the resolution goes as the diameter. That's why JWST has a 25 square-meter primary mirror, more than seven times larger than Hubble's.

JWST's primary mirror is constructed of 18 mirror segments, which are aligned on-orbit to form a single optical surface. The challenge for JWST is to make the mirrors lightweight for launch, but nearly distortion-free for excellent image quality.

Beryllium Mirror Segments, Axsys Technologies

An early investment in a multi-year development program has demonstrated that beryllium mirrors meeting the JWST mass and wavefront requirements can be made. Further testing, to be complete in June 2006, will show that the mirrors can survive launch. Manufacture of the flight mirror segments began during 2003 and currently all 18 are in machining; surface grinding has begun on one segment.

Wavefront Sensing and Control

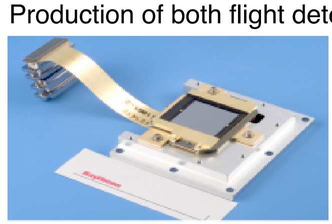
Wavefront Sensing and Control (WFSC) is the process used to align the JWST mirror segments. Through WFSC, the position of each mirror segment is measured and then adjusted to its correct position to produce a low telescope wavefront error. WFSC is accomplished by taking images of a star with a science instrument, and then processing the images through special algorithms that calculate the necessary mirror adjustments.

The algorithms have been proven through computer simulations and breadboard demonstrations that replicate a portion of the primary mirror. Successful algorithm tests have also been conducted on the Keck Observatory segmented mirror. The final demonstration will be accomplished using a subscale WFSC testbed that simulates all 132 degrees of freedom in the JWST telescope. This testbed has been used to prove six of the nine algorithms; the remaining three will be tested by December 2006.

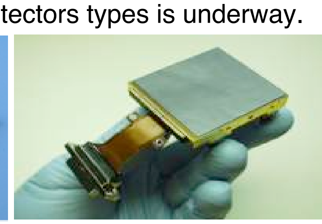
Infrared Detectors

JWST needs extraordinarily sensitive detectors to record the faint signals from far-away galaxies, stars, and planets, and it needs large-area detector arrays to efficiently survey the sky. JWST has extended the state of the art for infrared detectors by producing arrays that are both lower noise and larger format than their predecessors. It will use two types of detectors: four mega-pixel near infrared (IR) mercury-cadmium-telluride detectors for wavelengths 0.6-5 microns, and one mega-pixel mid-IR silicon-arsenic detectors for 5-29 microns.

In April 2006, testing of the near-IR detectors proved that they meet JWST requirements. Testing of the mid-IR detectors will be complete in July 2006. Production of both flight detectors types is underway.



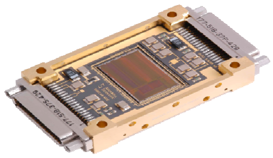
Mid-IR Detector, Raytheon



Near-IR Detector, Rockwell

Cryogenic Data Acquisition Integrated Circuit

To digitize the analog signals from the near-IR detectors, JWST is employing a low-noise, cryogenic application specific integrated circuit (ASIC). This ASIC advances the state of art for such devices by delivering a micro-processor with extremely low power dissipation and a 16 bit analog-to-digital converter with noise comparable to conventional warm electronics.



Cryo ASIC, Rockwell

The noise and power dissipation performance of the ASIC have already been demonstrated. By August 2006, it will be shown that the ASIC can withstand the launch and radiation environments.

Large, Precision Cryogenic Structure

The composite structure that holds the JWST primary mirror must be exquisitely stable to keep the segments in alignment. While dimensionally stable structures have been built before, the combination of the 50K operating temperature and stability to tens of nanometers is unique.

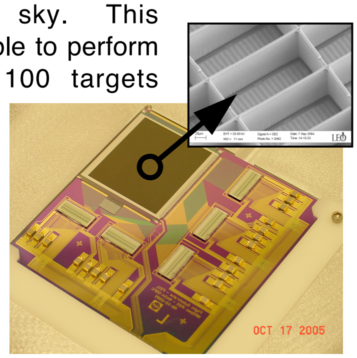
Stability Test Structure, ATK

To demonstrate the required performance, JWST has built a stability test structure using the techniques that will be used for the flight structure. Cryogenic stability tests will be done by November 2006.

Micro-shutters

Micro-shutters are tiny, 200 micron-wide cells with lids that open and close in response to the application of a magnetic field. The micro-shutters for JWST are formed into arrays of 171 x 365 cells. Each cell can be addressed individually, allowing it to be opened or closed as required to view (when open) or block (when closed) a portion of the sky. This adjustability makes it possible to perform spectroscopy on up to 100 targets simultaneously.

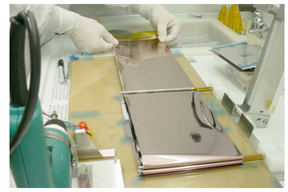
Tests have proven the ability of the micro-shutters to open and close 200,000+ times, more than double the required lifetime. Launch and radiation survival tests will conclude in August 2006.



Micro-shutter Array, NASA/GSFC

Sunshield Coating

The JWST telescope and instruments must be cooled below 50K to allow them to see faint infrared emissions from astronomical objects. The JWST design includes a large sunshield to block the heat of the Sun and Earth from reaching the cold section of the Observatory. The sunshield consists of five layers of Kapton with aluminum and doped-silicon coatings to reflect the sun's heat back into space.



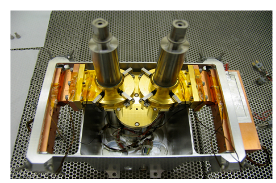
Silicon-coated Kapton, Sheldahl

Micrometeoroid, thermal, radiation, and mechanical tests to demonstrate the durability of the coatings were successfully completed in April 2006.

Heat Switches

The need to protect instruments from contamination during cool-down, and to decontaminate them in the event of an anomaly, requires the capability to warm the instruments. JWST uses heat switches to temporarily break the thermal path from the instruments to their radiators, allowing power-efficient warming of the instruments. The JWST heat switches are tailored for high conductance at 40K when closed.

Heat Switch, Space Dynamics Lab



A breadboard version of the JWST heat switch has already been built and tested, confirming the conductance value. Testing of a flight-like switch is scheduled to demonstrate all performance requirements by September 2006.

Cryocooler

The mid-IR detectors must operate at 7K to detect thermal emissions at wavelengths out to 29 microns. A high-efficiency pulse-tube cryocooler is being developed to provide this cooling capability. The JWST cryocooler is unique in that it provides cooling remotely: the cold head is close to the mid-IR detectors which are located approximately 20 meters from the cryocooler compressor and electronics.

Cryocooler, Northrop Grumman

A three year technology demonstration program has already proven the remote cooling capability. The program will conclude in December 2006 with the end-to-end test of a complete cryocooler system.

About JWST

JWST is an international collaboration among NASA, ESA, and CSA. The Goddard Space Flight Center manages JWST for NASA. The prime contractor is Northrop Grumman Space Technologies. The Space Telescope Science Institute will operate JWST. Launch is planned for 2013.

www.jwst.nasa.gov
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